Site Surveys of the Mine Burial/Coastal Processes Experiment Site at the WHOI Coastal Observatory, Martha's Vineyard

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LONG-TERM GOALS

The long-term goal of the Mine Burial Program is to develop a better understanding of the coastal processes driving mine burial in shallow water coastal environments.

OBJECTIVES

The scientific objectives of the Mine Burial Program are to develop specific models for mine burial driven by coastal processes, to carry out both laboratory and field programs designed to test these models, and to develop probability statements with respect to the likelihood of mine burial. Two field areas have been identified for this project, one off St. Petersburg, Florida and the second off Martha's Vineyard, Mass. The University of New Hampshire is providing support for these objectives through two separate efforts: 1- the development of a web-based database for the Mine Burial Program and; 2- the collection, processing and analysis of high-resolution multibeam sonar data at the Martha's Vineyard field area. In conjunction with investigators from the University of Texas (John Goff), the University of Hawaii (Roy Wilkins), the Naval Research Lab (Mike Richardson), the USGS (Bill Schwab), and Woods Hole Oceanographic Institution (Peter Traykovski), we will use both the sonar data and the database to investigate the statistical properties of sedimentological and morphological variability, as well as track changes in bedform morphology and other time dependent seabed processes.

APPROACH

Detailed seafloor mapping and characterization will be critical to the success of both the experimental and theoretical components of the mine burial program. While the sedimentary properties of any survey area must be described before we can understand mine burial processes, we must also understand the variability and areal distribution of sediments in the target location – necessary to understand the natural variability of the burial process. We cannot rely on a few samples in the target area, but rather we need to map and characterize the area as completely, and with as much detail, as possible. Furthermore, we also cannot rely on a single map. We expect the seafloor to change over time – from season to season, and as bedforms migrate along the seafloor (one of the important burial mechanisms). We need the capability to map both the morphology and sedimentary properties of the target area as frequently and inexpensively as possible.

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14. ABSTRACT

The scientific objectives of the Mine Burial Program are to develop specific models for mine burial driven by coastal processes, to carry out both laboratory and field programs designed to test these models, and to develop probability statements with respect to the likelihood of mine burial. Two field areas have been identified for this project, one off St. Petersburg, Florida and the second off Martha?s Vineyard, Mass. The University of New Hampshire is providing support for these objectives through two separate efforts: 1- the development of a web-based database for the Mine Burial Program and; 2- the collection, processing and analysis of high-resolution multibeam sonar data at the Martha?s Vineyard field area. In conjunction with investigators from the University of Texas (John Goff), the University of Hawaii (Roy Wilkins), the Naval Research Lab (Mike Richardson), the USGS (Bill Schwab), and Woods Hole Oceanographic Institution (Peter Traykovski), we will use both the sonar data and the database to investigate the statistical properties of sedimentological and morphological variability, as well as track changes in bedform morphology and other time dependent seabed processes.

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Our approach is to use multibeam sonar mapping to monitor the seafloor and its changes. Multibeam mapping is quick, relatively inexpensive, and maps can be generated in near real time. The detailed bathymetry provided by the latest technology is unparalleled and in addition, many the systems can produce georeferenced backscatter maps that may provide critical insight into the distribution of seafloor properties.

Another component of our effort is the "ground-truthing" of sidescan and multibeam backscatter data against the measured sedimentological and geotechnical properties of the seafloor. Other investigators are collecting sediment samples for physical and geotechnical properties (Goff), subbottom profiles (Wilkens and Schock) and super-high resolution pole mounted sector scanning sonar records (Traykovski and Richardson). In support of these efforts, we have deployed our *in-situ* sound speed and attenuation probe (ISSAP – see GEOCLUTTER report) to make *in-situ* measurements of the near-surface sediment properties.

To conduct the detailed high-resolution multibeam surveys we have chosen a Reson 8125 multibeam sonar. With its dynamic focusing and 0.5 degree beamwidths, the 8125 has demonstrated the ability to achieve higher resolution and faster ping rates than any other multibeam sonar presently available. Very precise positioning is also critical to achieve the highest resolution possible and to enable meaningful repeat surveys. Thus we have also established an array of kinematic DGPS positioning receivers on Martha's Vineyard and have had diver-deployed sonar reflectors emplaced in the survey are to act as fiducials for repeat surveys. Finally we have established and are maintaining the Mine Burial Web Site to act as a central repository for Mine Burial experiment data as well as a focal point for information exchange and analysis.

WORK COMPLETED

The Woods Hole mine burial field area covers water depths from 8-18 m, within a relatively confined area focused around an existing coastal observatory node – the Martha's Vineyard Coastal Observatory (MVCO). The MVCO is located in 12 m of water and provides both power and hard-wired data telemetry back to shore.

In February 2001, the USGS, in conjunction with Peter Traykovski, collected DF1000 sidescan sonar and boomer data in a small (2 x 3.5 km) area centered around the MVCO site. Seven months later, the USGS conducted a regional bathymetric and sidescan sonar survey using a 134 kHz Submetrix interferometric sonar. These surveys provided a baseline within which to plan our detailed multibeam sonar survey. They also provide a baseline from which to understand regional sediment movements.

In July 2002 , we conducted the initial (baseline) Reson 8125 multibeam survey aboard the SAIC vessel *Ocean Explorer*. The survey consisted of a super high-resolution (4 m overlap) survey in a small area surrounding the MVCO node and mine burial sites, a slightly lower resolution survey (12 – 25 m overlap) in a box approximately 1 x 1 km surrounding the "target box" and a lower resolution survey (25 – 40 m line overlap) in a 3 x 5 km region surrounding the 1 x 1 km box. The vessel, the operators, and the Reson 8125 performed flawlessly through a range of sea states. We completed all of the work scheduled at precisely the coverage levels planned.

Between 4 and 6 August, 2002, the UNH team also participated in a cruise aboard the *R/V Cape Henlopen*. This cruise was designed to collect core samples and *in-situ* measurements that will help us better understand the nature of the seafloor geology as well as better interpret the sidescan sonar and backscatter data already collected. On this cruise the UNH team deployed the *I*n situ *S*ound *S*peed and

*A*ttenuation *P*robe (ISSAP – see GEOCLUTTER 2003 annual report for a description) making numerous measurements of *in situ* sound speed and attenuation in the mine burial area. In addition newly constructed resistivity probes were deployed on ISSAP adding *in situ* determinations of porosity to the suite of measurements made.

The first full suite of instrumented mines and mine-like objects were deployed at the MVCO site during the first week in October 2003. Three more high-resolution Reson 8125 multibeam surveys (these aboard a 30 foot RHIB – the *Loughrea Scanner)* were conducted of the 1 x 1 km box around the mine burial "target area." The first was immediately after deployment of the mines in October 2003 (to capture the state of the seafloor and the mines at the time of initial deployment), the next was in December of 2003 and the final survey in April of 2004 immediately before retrieval of the mines.

In order to facilitate the analysis of the multiple and disparate data sets collected at the Martha's Vineyard experimental site, we have compiled all available data sets (multibeam, sidescan, seismic, core, etc.) into both a standard GIS (ArcView) and into an interactive georeferenced 3-D environment (Figure 1). These compiled data sets are also available on the mine-burial website.

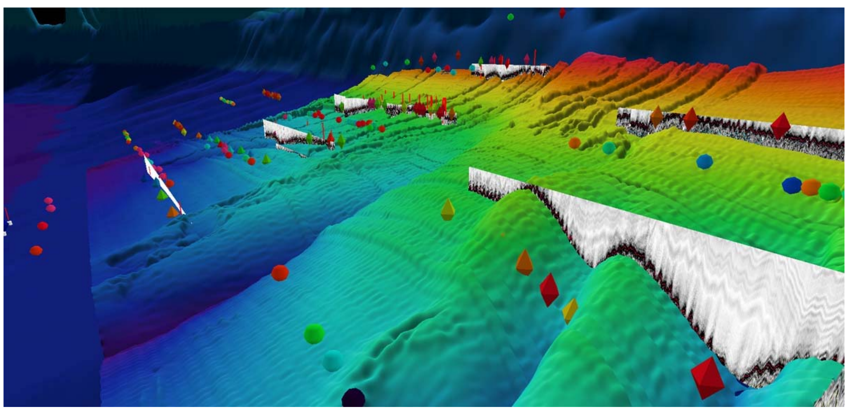

Figure 1. Scene from interactive 3-D view of MVCO database compilation. Plotted on bathymetry are core stations (red bars), velocity measurement sites (triangular polygons), grab samples (spheres) and seismic lines

RESULTS

The Reson 8125 continues to amaze us in its ability to resolve fine scale targets as well as produce large volumes of data; the total data volume for the four surveys exceeds 120 Gigabytes. Gridded data sets at various levels of resolution (from cm's to meters) have been generated and made available to other ONR researchers directly, and through the mine burial web site (see below). The node site and all diver-emplaced reflectors were clearly identified and most amazingly, we are able to resolve fields of individual ripples that are on the order of 2-5 cm in height (Figure 2, left). Of particular relevance to the mine burial program was our ability to resolve each of the mines as well as discriminate the type of mine (Fig. 2).

The repeat multibeam sonar surveys provided a detailed record of changes in the regional morphology over the time-period of the experiment. With the exception of the transient nature of the medium-scale bedforms in the fine-grained zones, the general characteristics of the regional morphology described above remained relatively constant over the period from July 2002 to April 2004 (e.g. the basic

structure of alternating shore-perpendicular zones of fine and coarse grained sands). There are, however changes in the nature of the boundaries of these zones. The boundaries between the zones appear to respond over periods of days to months to the predominant wave direction and energy. Smoothing and small shifts of the boundaries to the northeast take place during fair-weather wave conditions while erosion (scalloping of the boundary) and shifts to the north-northwest occur during storm conditions.

The multibeam sonar was also able to resolve changes in the orientation of individual ripples through the course of the repeat surveys (Fig. 3). The change in orientation of the ripples is once again directly related to the differences in the prevailing wave-direction. During the July, December and April surveys, the ripple crests are oriented orthogonal to the prevailing fair-weather wave direction and during the October survey the ripple crests are oriented orthogonal to the prevailing storm wave direction. The alignment of the small-scale bedforms with the prevailing wave conditions appears to occur rapidly (on the order of hours or days) when the wave conditions exceed the threshold of sediment motion (most of the time for the fine sands) and particularly during moderate storm conditions. During storm events, erosional "windows" appear in the fine-grained sands that are oriented parallel to the prevailing wave direction and reveal orbital-scale ripples that are oriented perpendicular to the prevailing wave direction (Fig. 3). One of these erosional "windows" formed upstream of the MVCO tower and was probably the result of turbulent eddies shed by the tower but others were found in regions where there was no obstruction to the flow indicating that bursts of turbulence may be an initiating factor in forming the ripple scour depressions (Fig. 2).

The multibeam sonar was also able to clearly locate and even identify individual mines and their state of burial in the fine-grained sediment zones (Fig. 2). The resolution of the multibeam sonar combined with 3-D visualization techniques provided realistic looking images of the both the instrumented mines and mine shapes (including a Manta and RockAn shape) that were dimensionally correct and enabled unambiguous identification of the mine type. In two of the surveys (October and December 2004) the mines in the fine-grained sands scoured into a scour pit but were still perfectly visible and identifiable. These mines may not have been visible on standard, towed side-scan sonars as they were in scour pits below the ambient seafloor level. In the April 2004 survey the mines were completely buried. In the coarse-grained sand zone, however, the mines are extremely difficult to detect once there has been sediment movement in the region. This is due to the fact that in the coarse-grained sands where large wave orbital-scale ripples are present, the mines bury until they present the same hydrodynamic roughness as the orbital scale bedforms (10 – 15 cm). The result is striking and somewhat counter-intuitive in that it demonstrates that the mines are more difficult to find in coarse, rippled sand zones than they are in fine sand zones, even though they are less buried (in terms of depth below the ambient seabed) in the coarse sand.

The detail and coverage provided by the multibeam sonar along with the ability to render and visualize the sonar results in 3-D offer several approaches to measuring the degree of burial of the mines at the snapshots in time represented by the multibeam surveys. Given the relatively large, three-dimensional, spatial coverage of the multibeam sonar, the depth of the "ambient seafloor" can be determined quantitatively through a statistical examination of the seafloor surrounding the mine or through the construction of a profile (or several profiles) across the seafloor surrounding the mine site. Similarly, the depth of the scour pit and/or the top of the mine can be measured directly through profiling across the scour pit or the mine With an *a priori* knowledge of the dimensions of the mine both the depth of burial below the ambient seafloor and the burial by surface area covered can be determined. In the absence of *a priori* knowledge of the dimensions of the mine, the multibeam sonar can also provide an

estimate (limited in accuracy by the resolution of the multibeam sonar and the gridding process) of the dimensions of the mine. The three-dimensional nature of the multibeam sonar data also allows the direct determination of the volume of material removed from a scour pit around a mine through the calculation of a difference surface between the plane and the region of the scour and mine. Finally, the three-dimensional nature of the multibeam sonar data allows for the direct visualization of the state of mine burial at the snapshot in time during which the survey takes place.

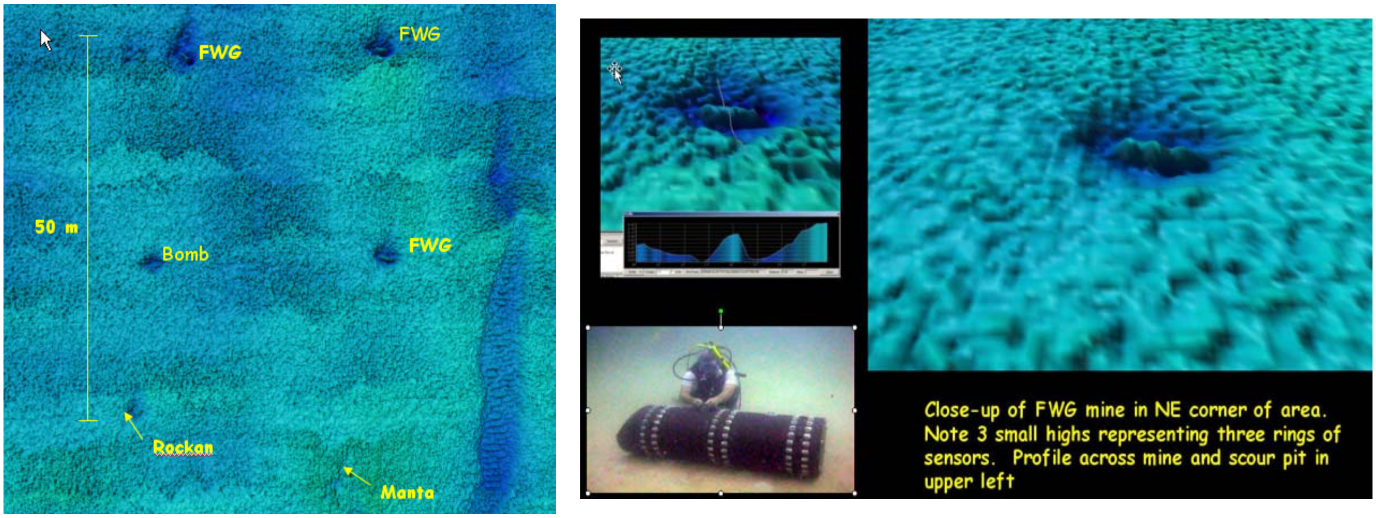

Figure 2 (left). Reson 8125 data showing 6 mines after deployment in October 2003. Each of the mine types can easily be recognized by its shape. Also note the eroded patches filled with ripples to the east (right) of the mines. These were not visible in earlier surveys and were subsequently covered in later surveys. (Right) - Close-up of NRL/FWG instrumented mine. Note three rings of sensors and sloped side that are clearly visible in the multibeam data.

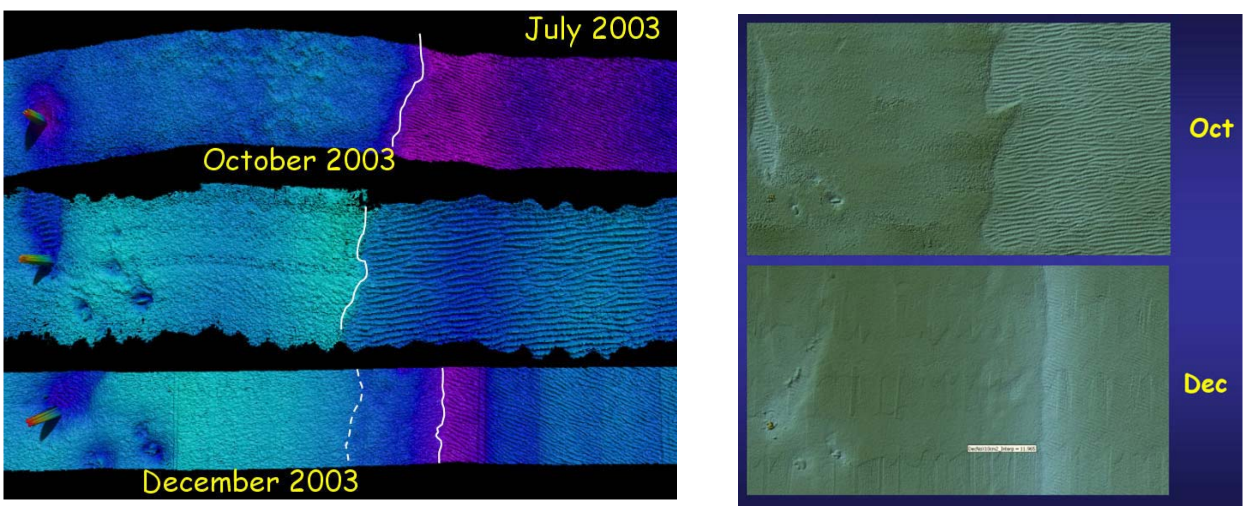

Figure 3. (Left) - Results of three surveys of node area—the MVCO node is seen on the left of each imag, on local topographic high composed of medium to fine sand. On right of each image is local topographic low with ripples developed in coarse sand. A sharp topographic boundary between the fine-med grained high and the coarse grained low is marked in white. July – no mines -- small (2-5 cm) ripples oriented NW-SE. October survey shows mines around node and larger (8-15 cm ripples) oriented E-W. Note scour behind node.

Results from the deployment of the ISSAP were equally successful. During the three-day August cruise, 102 acoustic (sound speed and attenuation) and resistivety (porosity) stations were occupied representing more than 62,000 discrete measurements and more than 30 Gigabytes of data. At nine stations we were able to make measurements at two different frequencies (100 and 65 kHz) and at about half the stations continuous measurements were made as the probes entered the interface. Data quality is very high with measurement accuracy of +/- 0.5 – 1 m/sec for sound speed and +/- 1dB/m for attenuation. Even in this region of relatively limited sediment diversity, the sound varied from 1575 m/sec to 1806 m/sec and attenuation from 6.5 to 59.3 dB/m at 65 kHz. The greatest variation in both sound speed and attenuation appears to be associated with the finer-grained sediments that are less unimodal than the pure coarse-grained sediments consistent with geoacoustic models for both sound speed and attenuation.   Dual frequency measurements (at 65 and 100kHz) showed no measurable velocity dispersion. Future work will look at lower frequencies.

Finally the Mine Burial Website is up and available to the community at http://www.mbp. unh.edu. This site contains background information on the program, participant and meeting lists, as well as all data that has been made available to us.

IMPACT/APPLICATIONS

The multibeam surveys have provided the morphological and sedimentological context for all investigators as well as demonstrated the ability to directly detect very small features and identify mine (including their type) on the seafloor. The ability to readily detect mines in the fine-sand environment and the difficulty in detecting them in the coarse sand environment has important ramifications for mine placement and hunting. The multibeam data has provided an understanding of the distribution of very small-scale bedforms and topography (like the scour-pit) at a scale unobtainable by other means. This, in turn, will hopefully be of tremendous value to the modelers. With ground-truthing studies we hope to gain insight into the mechanisms of sediment transport and the potential for using backscatter to better understand seafloor property changes at the test site. The database will become the central repository for all project related work as well as providing the project team and others the tools necessary for efficient data exploration.

TRANSITIONS

Lessons learned about mine detection with multibeam and sidescan sonar during this work and example data sets from the Martha's Vineyard experiment site have been incorporated into a training course for NAVO and U.S. Navy EOD specialists.

RELATED PROJECTS

GEOCLUTTER, Uncertainty DRI, and RIPPLES DRI.

PUBLICATIONS

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